

# NOTES ON ASTEROIDS IN THE BRITISH MUSEUM (NATURAL HISTORY)

## III.<sup>1</sup> *LUIDIA*

By AILSA M<sup>c</sup>GOWN CLARK

(With Plates 39-46)

THE following species of the genus *Luidia* are represented in the Museum collection; those of which the types are held are marked with an asterisk and those commented on in the text, with a dagger:

- |  |   |
|--|---|
| <i>aciculata</i> Mortensen                                       | <i>*longispina</i> Sladen                                     |
| <i>*†africana</i> Sladen   | <i>maculata</i> Müller & Troschel, with forma                 |
| <i>alternata</i> (Say), with subspecies <i>†numidica</i> Koehler | <i>†herdmani</i> forma n.                                     |
| <i>*†aspera</i> Sladen   | <i>magnifica</i> Fisher ( <i>†</i> under <i>aspera</i> )      |
| <i>atlantidea</i> Madsen ( <i>†</i> under <i>africana</i> )      | <i>mauritiensis</i> Koehler                                   |
| <i>avicularia</i> Fisher   | <i>neozelanica</i> Mortensen                                  |
| <i>bellonae</i> Lütken   | <i>penangensis</i> de Loriol                                  |
| <i>ciliaris</i> (Philippi)                                       | <i>phragma</i> H. L. Clark                                    |
| <i>clathrata</i> (Say)   | <i>prionota</i> Fisher  |
| <i>*†columbia</i> (Gray)   | <i>†quinaria</i> von Martens (incl. <i>*limbata</i> Sladen)   |
| <i>elegans</i> Perrier ( <i>†</i> under <i>africana</i> )        | <i>sarsi</i> Düben & Koren ( <i>†</i> under <i>africana</i> ) |
| <i>foliolata</i> Grube   | <i>†savignyi</i> (Audouin)                                    |
| <i>*†hardwickii</i> (Gray) (incl. <i>*forcifer</i> Sladen)       | <i>*†scotti</i> Bell.   |
| <i>*heterozona</i> Fisher  | <i>senegalensis</i> (Lamarck)                                 |
|  | <i>tessellata</i> Lütken ( <i>†</i> under <i>columbia</i> )   |

Sladen's very full descriptions of the 'Challenger' material are excellent in themselves, but examination of the type specimen of *Petalaster hardwickii* Gray shows that *L. forcifer* Sladen is a synonym of this. Gray's description was, as usual, very brief and inadequate in the light of the many species since described. His type specimen is accordingly dealt with in detail here, as are the types of Bell's species *Luidia scotti* from off Rio de Janeiro. *L. doello-juradoi* Bernasconi (1941) seems to be identical with the latter. Sladen's types of *Luidia aspera* were found to include specimens of two other species, so that only the one described by him is left as the holotype.

The very fine 'Siboga' report on *Luidia* by Döderlein (1920) provides a valuable subdivision of the genus and a comprehensive survey of the species known up to that time. The following species (see p. 380) have been described since 1920 or were not included by Döderlein.

Döderlein's four main groups are most convenient for splitting up this unwieldy genus into more manageable units, but the limits between them are not absolutely sharp. For instance, *L. scotti* Bell bridges the gap between the *Clathrata* and *Alternata* groups. Also the subgenus *Integraster* with such species as *L. avicularia* Fisher and

<sup>1</sup> Notes I and II appeared in *Novit. Zool.* 42 (1948) and *Bull. Brit. Mus. (Nat. Hist.) Zool.* 1 (4) (1950) respectively.

Name	Locality	Group
<i>moroisoana</i> Goto, 1914: 301	Japan	<i>Quinaria</i>
<i>yessoensis</i> Goto, 1914: 306	"	"
<i>superba</i> A. H. Clark, 1917: 171	Pacific coast of Colombia	<i>Alternata</i> (?)
<i>porteri</i> A. H. Clark, 1917a: 153	Chile	<i>Ciliaris</i> (?)
<i>scotti</i> Bell, 1917: 8	Off southern Brazil	<i>Clathrata</i>
<i>neo-zelanica</i> Mortensen, 1925: 278	New Zealand	<i>Ciliaris</i>
<i>varia</i> Mortensen, 1925: 275	"	<i>Alternata</i>
<i>aciculata</i> Mortensen, 1933: 425	St. Helena	<i>Ciliaris</i>
<i>hexactis</i> H. L. Clark, 1938: 73	NW. Australia	<i>Quinaria</i>
<i>heterozona</i> Fisher, 1940: 265	W. Africa	"
<i>mortenseni</i> Cadenat, 1941: 53 (= <i>heterozona</i> )	"	"
<i>doello-juradoi</i> Bernasconi, 1941: 117 (= <i>scotti</i> )	Argentina	<i>Clathrata</i>
<i>patriae</i> Bernasconi, 1941: 117	"	"
<i>quequenensis</i> Bernasconi, 1942: 253	"	<i>Alternata</i>
<i>bernasconiae</i> A. H. Clark, 1945: 19 (= <i>alternata</i> )	NW. Atlantic	"
<i>atlantidea</i> Madsen, 1950: 192	W. and NW. Africa	<i>Ciliaris</i>

*L. heterozona* Fisher joins up the *Quinaria* and *Ciliaris* groups. Indeed, Fisher (1940: 265) puts the last-named species actually in the *Ciliaris* group and Döderlein himself in his 'family tree' of the genus (p. 223) illustrates the link up of the two groups through the subgenus *Integraster*.

As Mortensen (1925: 281) says, in discussing *L. neozelanica*, most of the species belonging to the *Ciliaris* group are distinguished by apparently trivial characters, coupled with their geographical location. This certainly applies to the three species *L. sarsi* from western Europe, *L. atlantidea* from West and North-West Africa, and *L. africana* from South Africa, in which the differing form and location of the pedicellariae and the size of the paxillar spinelets provide the main characters by which they can be recognized.

However, it seems to me that too much importance has sometimes been placed on the occurrence or non-occurrence of pedicellariae as a specific character, rather than on their shape. For instance, *Luidia sibogae* Döderlein (p. 262) is based on a single juvenile specimen with R = only 19 mm., so it is not surprising that pedicellariae are only found in the interbrachial angles. The only other character in which it seems to differ from typical *L. savignyi* (Audouin) is in having unusually large spine-bearing paxillae, itself a somewhat variable feature in the latter species. Döderlein himself suggests that it may only be a young specimen of *L. savignyi*. Similarly I am doubtful of the specific value of *L. mascarena* Döderlein (1920: 261) as distinct from *L. savignyi* also. The few specimens known from Mauritius and South-East Africa seem to have few, if any, ventro-lateral pedicellariae, but this is, in my opinion, at most a sub-specific distinction and anyway may not be borne out by a good series of adult specimens.

At one time *Luidia ciliaris* (Philippi) was thought to have an Atlantic variety which was called *normani*, distinguished from the typical Mediterranean form by the possession of trivalved rather than bivalved ventral pedicellariae. However, even Ludwig, the initiator of this variety, abandoned it on the evidence of further material, as, I suspect will also be the case with some of the other forms of *Luidia*.

In the text that follows the reference lists quoted are not necessarily complete.

## CLATHRATA GROUP

*Luidia columbia* (Gray)

TEXT-FIGS. 1 and 2, PL. 39, FIG. 1

*Petalaster columbia* Gray, 1840: 183.non *Luidia columbia*, H. L. Clark, 1910: 331, pl. 1, fig. 2; Döderlein, 1920: 253; Bernasconi, 1943: 7, pl. 4, figs. 2 and 3 (= *L. tessellata* Lütken).*Luidia brevispina* Lütken, 1871: 288; Döderlein, 1920: 253, figs. 10, 14, and 22.

Type: R/r = 58-65 mm./12 mm. = 5/1. San Blas. Cuming collection.

The specimen is dry and not in a very good condition. The ventral side seems to have been coated in glue particularly at the interbrachial angles which are distorted. Most of the spines, short as they are, have become adpressed to the surface or broken off.

NOTE: Gray has obviously assumed that the specimen came from the San Blas on the Atlantic side of the isthmus of Panama, which was at that time part of Colombia, hence his specific name. I am unable to trace any place called San Blas on the Pacific coast of Colombia, but there is a town of that name on the west coast of Mexico near Mazatlan, where other similar specimens have been taken (the types of *L. brevispina* Lütken). Since Cuming only collected on the west coast of Central America and some shells from his collection are recorded as coming from 'San Blas, Gulf of California' it is presumably from there that this specimen came.

DIAGNOSIS. A species of *Luidia* belonging to the *Clathrata* group of Döderlein, with two rows of lateral paxillae forming transverse rows with the larger supero-marginal series; dorsal paxillae with large, flat, polygonal, central granules surrounded by much more slender peripheral spinelets; no pedicellariae; one very short, tapering marginal spine just below the ambitus on each infero-marginal plate, with two shorter flattened ones above it; ventral infero-marginal spines very short and squamiform; the single ventro-lateral plates hardly projecting from underneath the inner ends of the corresponding infero-marginals; three relatively short, thick adambulacral spines.

DESCRIPTION. The largest dorsal paxillae are the supero-marginals which are proximally wider than long but distally become square. They form transverse series with the two outermost lateral rows of paxillae, which are square (or slightly wider than long) proximally, becoming relatively longer distally. Towards the middle of the rays the paxillae become smaller and more irregularly arranged, having about seven flat, polygonal, central granules as compared with the twelve or so of the supero-marginal series. The peripheral spinelets around the paxillae are much more slender.

There are no pedicellariae on either side.

The infero-marginal plates are, as usual, very short and raised into a ridge extending a little way on to the dorsal side, where they bear a few short stumpy spinelets. On the ambitus, or just above it, are two (rarely one), short, flattened spines, expanded outwardly rather like a hoof seen in side view. Below these comes a single short tapering spine, about half as long again as the two above it but, even so, not as much as 1 mm. in length. On the ventral side there are two somewhat irregular rows of expanded, squamiform spinelets, with smaller peripheral ones on either side.

The ventro-lateral plates are largely overlain by the infero-marginals so that only a small lobe protrudes. It is impossible to tell how many there are in the inter-brachial angle owing to the poor condition of the specimen. They do not appear to bear any distinct armature, although possibly they may carry a squamiform spinelet similar to and consecutive with the infero-marginal spinelets.

The adambulacral plates have the usual curved, compressed furrow spine followed by two other spines, the middle one being slightly curved at the base, otherwise

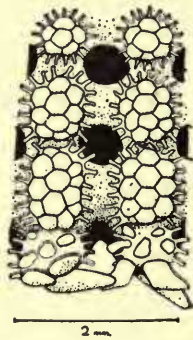


FIG. 1.

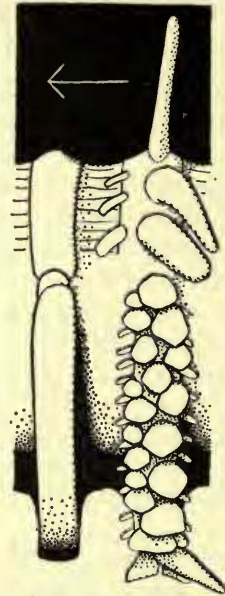


FIG. 2.

TEXT-FIG. 1. *Luidia columbia* (Gray). Type. Dorsal view of two infero-marginal plates and the adjacent paxillae from the proximal part of an arm.

TEXT-FIG. 2. *Luidia columbia* (Gray). Type. Ventral view of one side of two segments, that on the left having been treated with sodium hypochlorite. (The arrow points towards the mouth.)

cylindrical and gently tapering, while the outer one is stouter and a little shorter. There may be several spinelets along the adoral edge of each adambulacral plate, of which one on a level with the outermost large spine may be enlarged occasionally.

There is a faint tinge of greenish colour on the dorsal side.

REMARKS. Lütken, H. L. Clark, and Döderlein have all had a mistaken impression of this species, which is hardly surprising after Gray's very brief diagnosis, for Lütken when describing *L. tessellata* (1859: 40) from Puntarenas (on the west coast of Costa Rica) queried it as a possible synonym of *Luidia columbia*, which it is not, and later (1871: 288) described as a separate species *L. brevispina* from Mazatlan, Mexico, which is clearly identical with *L. columbia*.



There are two specimens in the British Museum identified as *Luidia tessellata* by Lütken and labelled as coming from Realejo, Puntarenas (the type locality). These fully agree with the description Döderlein has given for *Luidia columbia* (p. 253), having long slender marginal and adambulacral spines. The longer of the two ambital spines (the lower one) is 3.5-4 mm. in length, while the upper one is usually about 2 mm. long. The adambulacral spines are about 3 mm. long and with the slender spines on the ventral surface of the infero-marginal plates give the under side a 'shaggy' appearance quite distinct from that of *Luidia columbia* with its very abbreviated armature.

*Luidia tessellata* is then a valid species and it is *L. brevispina* which is the synonym of *Luidia columbia* (Gray).

As for *Luidia marginata* Koehler (1911a: 17) from Mazatlan, Döderlein (p. 251) says that it differs from *L. brevispina* (i.e. *columbia*) in having numerous interradial ventro-lateral plates in the interbrachial angles, although Koehler himself makes no mention of this. It is unfortunate that the type of *L. columbia* is in such a condition in this region that no comparison can be made.

ALTERNATA GROUP

*Luidia scotti* Bell

TEXT-FIG. 3; PL. 40, FIG. 1

*Luidia scotti* Bell, 1917: 8.

*Luidia doello-juradoi* Bernasconi, 1941: 117; 1943: 8, pl. 1, fig. 3, pl. 2, figs. 2-3, pl. 3, figs. 4-5.

St. 42. 'Terra Nova' Expedition. 22° 56' S.: 41° 34' W. (off Rio de Janeiro). 73 m. 15 specimens.

Holotype selected by A. M. Clark with  $R = 60$  mm.,  $r = 8$  mm.,  $R/r = 7.5/1$ , br. = 9 mm., British Museum registered number 1915.2.1.64.

DIAGNOSIS. A species of *Luidia* linking the *Alternata* and *Clathrata* groups, with two lateral rows of paxillae forming transverse rows with the supero-marginal series; no dorsal pedicellariae but three- or four-valved ones are present on most of the ventro-lateral plates in the interbrachial angles and at the bases of the arms; one large marginal spine at the ambitus with a smaller one above it and four or five others below on the ventral face of the plate, all of them much smaller than the ambital spine; four adambulacral spines, the outermost two placed on a line parallel to the furrow.

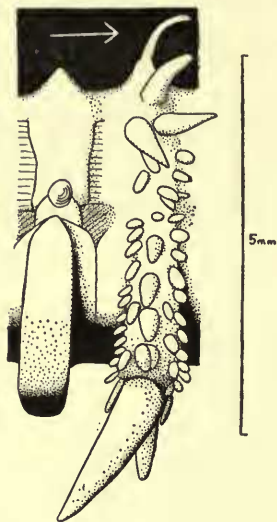
DESCRIPTION. The sides of the rays are almost vertical up to the second row of paxillae in from the supero-marginal series. The centre of the disk and rays is quite flat. The madreporite is concealed.

The supero-marginal paxillae are square or slightly longer than wide. Forming transverse rows with them are two series of lateral paxillae, of which the outer row, at least, are wider than the supero-marginals. Across the middle of the ray there are about thirteen rows of less regularly arranged plates, which become progressively smaller towards the mid-radial line. The small central plates, both of the disk and the arms, bear three or four short, thick, spaced paxillar spinelets surrounded by about twelve thinner peripheral ones. The number of spinelets on each paxilla increases

towards the sides of the rays to the outermost lateral series, each plate of which bears about twelve central and thirty peripheral spinelets. All the paxillar spinelets have the rounded tops distinctly thorny under magnification.

There are no dorsal pedicellariae.

The infero-marginal plates are mainly ventral in position but have a small area covered with paxillar spinelets on their uppermost edge at the side of the arm. Below this, at the ambitus of the ray, is a large, pointed, curved spine about 2.5 mm. in length. Above this is a smaller spine, usually about 1 mm. long, although rarely it is two-thirds as long as the ambital spine. On the ventral side of each infero-marginal plate is a series of four or five much smaller pointed spines, slightly flattened, one being occasionally replaced by a pedicellaria as in the figure. The outermost is the largest and measures just over 1 mm. in length. On each side of this row there may be a series of smaller, stumpy spines, while on the edges of the plates are the usual fringing spinelets.



TEXT-FIG. 3. *Luidia scotti* Bell. Type. Ventral view of one side of two arm segments, that on the left having been treated with sodium hypochlorite. (The arrow points towards the mouth.)

The adambulacral plates have a curved, sabre-like furrow spine backed by a larger tapering one, followed in turn by a pair of spines of which either the adoral may be smaller while the other is the same size as the second spine, or else both of them are smaller. On the outer edge of the plate lie one or two smaller spines or spinelets. In the interbrachial angle each ventro-lateral plate bears a three- or four-valved pedicellaria, but these only extend on to the proximal part of the ray up to about the sixth joint, beyond which there are only spinelets. There are no pedicellariae on the mouth plates.

The colour has been lost in the type after thirty-five years in spirit, but some other specimens are dark brown along the middle of the rays while a small one has brown blotches at intervals across the arms, as Bell

described when the material was fresh.

**VARIABILITY.** A paratype slightly larger than the specimen described above has the ventro-lateral pedicellariae extending on to most of the plates in the proximal half of the arm, not just on those in the interbrachial angle.

The long narrow arms with an R/r ratio of 7 (or more)/1 are found in all the specimens from this station.

**REMARKS.** Bell compared this species with *Luidia clathrata* (Say), but the relatively smaller supero-marginal paxillae compared to the outermost lateral series and the presence of pedicellariae and blotched coloration readily distinguish his own species. These characters are more typical of the *Alternata* group of Döderlein than of the *Clathrata* group.

The affinities of *Luidia scotti* are obviously with the species included in Döderlein's subgenus *Armaster*, particularly *L. armata* Ludwig (1905: 85) and *L. ludwigi* Fisher

(1906a and 1911). However, without Pacific material for comparison it cannot be decided whether the forms on both sides of South and Central America represent the same species. They are certainly very closely related.

*Luidia scotti* is obviously identical with *L. doello-juradoi* Bernasconi (1941) from the mouth of the river Plate. The type of that species also has supero-marginal paxillae equal in length to, but not so wide as, the outermost lateral row and three- or four-valved pedicellariae on the ventro-lateral plates. The only difference appears to be that the two marginal spines are almost equal in length in *L. doello-juradoi*, whereas in the types of *L. scotti* the upper one is usually less than half the size of the lower.

It is unfortunate that Bell's description was so brief and omitted any mention of the distinctive pedicellariae.

***Luidia savignyi* (Audouin)**

PL. 40, FIG. 2

*Asterias savignyi* Audouin, 1826.

*Luidia savignyi*, Gray, 1840: 183; Perrier, 1875: 342; Koehler, 1910: 10, pl. 1, fig. 5, pl. 6, fig. 3.

*Luidia mascarena* Döderlein, 1920: 261, fig. 5.

Number	B.M. Reg. No.	Locality	Source
1	1903.4.2.39	Wasin, N. of Zanzibar, 10 fms.	Crossland collection
1	1904.3.3.66	Pearl Bank, Ceylon	Herdman collection
2	69.6.25.9-10	Gulf of Suez	R. McAndrew
1	1951.1.6.1	28° 32' S.: 32° 26' E., NE. of Durban, 20 m.	Cape Town University
1	1927.1.10.90	Suez	C.U. Suez Canal Expedition

REMARKS. *Luidia mascarena* Döderlein, from Mauritius, apparently only differs from *L. savignyi* in lacking ventro-lateral pedicellariae. This is the case with Döderlein's two specimens and with de Loriol's one, according to Koehler. The specimen from north-east of Durban, with R = 140 mm., has a single pedicellaria on each side of each interbrachial angle, usually on the third or fourth plate, and three or four others farther out on the arm. The Wasin specimen is unfortunately juvenile with R = only 35 mm. It has a total of three ventral pedicellariae, of which two are in one interbrachial angle. The Suez specimen collected by the Cambridge University Expedition (R = 38 mm.) has no ventral pedicellariae at all, as remarked on by Mortensen (1926: 121), although the other two from the same locality, collected by McAndrew, both have pedicellariae on most of the ventro-lateral plates. They are, however, much larger (R = 95 mm. or more).

The specimen from Pearl Bank, Gulf of Manaar (Pl. 40), is that 'with spines on the surface of its rays', this comment of Bell's being reproduced under *Luidia hardwicki* in Herdman's report (1904: 143). The dorsal spines certainly are numerous and very large, measuring about 4 mm. in length. R = 50 mm. Coupled with the powerful dorsal armature, the ventral spines and pedicellariae are unusually long for the species. But for the degree of development of the spines there seems to be little difference between this form and typical *L. savignyi*. More material is needed to show whether it comes within the range of variation of the latter.

The dark patches on the arms of this species when seen through a lens are shown to



be produced by pigmentation on the surfaces of those paxillae which come within the tinted area, extending on to the bases of the paxillar spinelets. This throws into sharp contrast the white tips of the spinelets. In the smaller specimens there is often only a single central spinelet on the mid-radial paxillae.

All of these specimens are seven-rayed in marked contrast to the two five-rayed ones from Madagascar remarked on by Koehler (1910: 14) in his own collection. He says 'les pédicellaires sont particulièrement abondants', which does not seem to be the case in the few seven-rayed specimens of *L. savignyi* known from Mauritius on one side and the coast of South-East Africa on the other. Koehler could not find any other character by which to separate this five-rayed form from the more widespread seven-rayed one.

The very large nine-rayed specimen from Mauritius recorded by Bell (1889: 422) and purchased from M. de Robillard is not *L. savignyi* but *L. mauritiensis* Koehler (1910: 15, pl. 1, figs. 6-7), a species more nearly related to *L. magnifica* Fisher, from the Hawaiian Islands with ten arms and *L. aspera* Sladen from the Philippines, with eight, also having dorsal spines on many consecutive plates. A second specimen actually had ten rays originally, but all have been broken off and nine pieces splinted on to the disk neglecting to leave a gap, so that from the dorsal side nine appears to be the actual number. It is dried and altogether in a bad state.

### *Luidia aspera* Sladen

TEXT-FIGS. 4 and 6

*Luidia aspera* Sladen, 1889: 248, pl. 43, figs. 1-2, pl. 45, figs. 9-10.

Of the original four types of this species, the two young ten-rayed specimens, each with  $R =$  about 40 mm., and a slightly longer odd arm, are obviously not the same as the two large ones from Zamboangan, in the Philippines, in 10 fathoms, as for one thing they do not have blotched coloration. These two small specimens, from 'Challenger' stations 204, off Tablas Island, Philippines, in 100 fathoms, and 209, north of the Admiralty Islands in 150 fathoms, are *Luidia avicularia* Fisher, a species belonging to the *Quinaria* group.

The remaining two specimens, one with eight, the other with ten rays, are otherwise superficially similar, having blotched coloration and several rows of lateral paxillae with erect spines on many consecutive plates. However, closer examination shows that they differ in a number of ways.

Both of them have  $R = c.$  170 mm., but in the ten-rayed specimen the disk diameter is 45 mm. and in the eight-rayed one only 35 mm. The latter has much longer and more slender three-bladed pedicellariae, numbering at the most two to each segment, whereas in the ten-armed one there are three ventrolateral plates and correspondingly three pedicellariae (at least proximally), which are also shorter and more abruptly tapering. This is obviously a specimen of *Luidia magnifica* Fisher (1906: 1033), the type of which, also ten-rayed, came from the Hawaiian Islands in 43-73 fathoms. The eight-rayed specimen, which Sladen described and figured, is thus left as the only type of *Luidia aspera*.



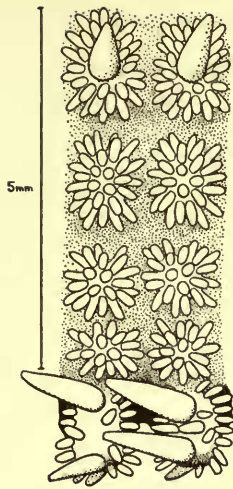


FIG. 4.

TEXT-FIG. 4. *Luidia aspera* Sladen. Type. Dorsal view of the upper ends of two infero-marginal plates and the adjacent paxillae.

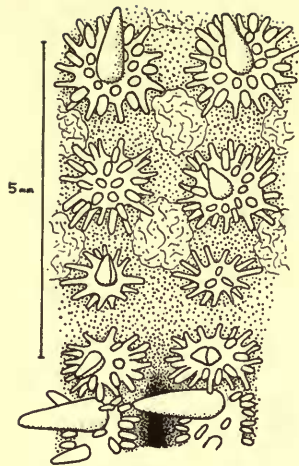


FIG. 5.

TEXT-FIG. 5. *Luidia magnifica* Fisher. Dorsal view of the upper ends of two infero-marginal plates with the adjacent paxillae, showing the papulae between the plates.

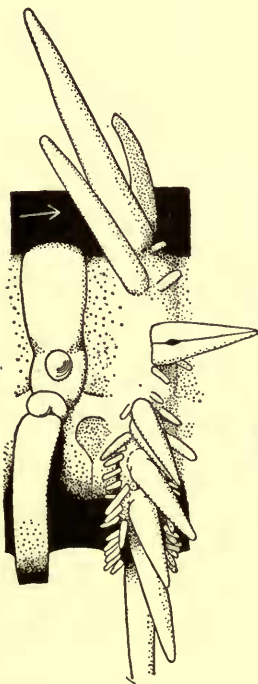


FIG. 6.

TEXT-FIG. 6. *Luidia aspera* Sladen. Type. Ventral view of one side of two segments, that on the left having been treated with sodium hypochlorite. (The arrow points towards the mouth.)

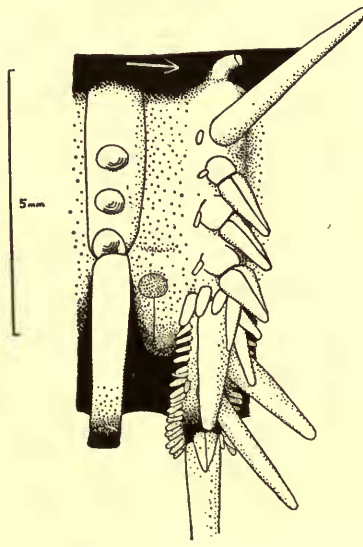


FIG. 7.

TEXT-FIG. 7. *Luidia magnifica* Fisher. Ventral view of one side of two segments, that on the left having been treated with sodium hypochlorite. (The arrow points towards the mouth.)

The differences between the two species can be listed as follows:

- | <i>L. aspera</i>  | <i>L. magnifica</i>   |
|---|---|
| 1. Eight rays.  | 1. Ten rays.  |
| 2. Dorsal spines present on the paxillae of the third to the fifth (sixth) lateral rows, counting in from the supero-marginal series. | 2. Dorsal spines present on the paxillae of the second to fourth (fifth) lateral rows, counting in from the supero-marginal series. |
| 3. No pedicellariae on the supero-marginal plates.  | 3. Pedicellariae present on the supero-marginal and some of the first lateral series of paxillae.                                   |
| 4. Ventral pedicellariae about three times as long as their basal width.  | 4. Ventral pedicellariae only twice as long as their basal width.   |
| 5. Two ventro-lateral plates occur on each side of each segment.  | 5. Three ventro-lateral plates present on each side of each segment.  |
| 6. Three large adambulacral spines.   | 6. Two large adambulacral spines.   |
| 7. Furrow spine long.   | 7. Furrow spine rather short.   |

The accompanying comparative illustrations (Text-figs. 4-7) of these two specimens help to emphasize these differences.

The occurrence of these two species together suggests that the eight-rayed *Luidia hystrix* Fisher (1906: 1032), also from the Hawaiian Islands in depths of 14-52 fathoms, is probably identical with *L. aspera*. The differences mentioned by Fisher are that in *L. aspera* only three rows of lateral paxillae are spiniferous and there are only three adambulacral spines but two pedicellariae on many segments, whereas in *L. hystrix* nearly all the dorsal paxillae are spiniferous, there are four adambulacral spines, and pedicellariae only occur on about half the segments and then never more than one at a time. I believe these three differences are all subject to variation, but to what extent can only be settled by further material.

The minor differences between the 'Challenger' specimen of *L. magnifica* and the type of that species, which has R = 330 mm., are all in my opinion attributable to the great size of the latter.

The seven-rayed specimen from Mozambique, recorded as *Luidia aspera* by Simpson and Brown (1910: 49) clearly belongs to *L. savignyi* (Audouin), as noted by Fisher (1919: 171).

*Luidia aspera* is certainly very closely related to *L. savignyi*, and apart from having eight rays rather than seven, the only notable difference seems to be that *L. aspera* has relatively small dorsal spines occurring on many consecutive lateral paxillae, whereas in *L. savignyi* the spines are rather more robust and usually only occur sporadically on the lateral series of paxillae.

### *Luidia alternata numidica* Koehler

PL. 41, FIG. 1

*Luidia numidica* Koehler, 1911: 3, pl. 1, figs. 8-11.

*Luidia alternata* var. *numidica* Madsen, 1950: 206, text-fig. 9.

There are five specimens of this subspecies in the Museum collections, of which one from Boa Vista Island in the Cape Verde group, collected by Crossland, has particularly numerous spine-bearing paxillae in the second and third (rarely in the fourth)

rows inwards from the supero-marginals. On the other paxillae the peripheral spinelets are distinctly more slender than the shorter central ones, as in typical West Atlantic *L. alternata*, not like the type of *numidica*. Indeed, this specimen is very near typical *Luidia alternata*.

*Luidia maculata* forma *herdmani* forma n.

TEXT-FIG. 8; PL. 41, FIGS. 2 and 3

Pearl Bank, Gulf of Manaar, Ceylon. Herdman collection. 1904.3.3.8-9. 3 specimens (2 very young).

Tuticorin, Madras. Thurston collection. 88.I.2.64. 1 specimen.

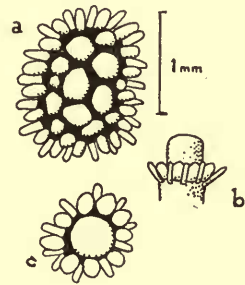
Type: larger specimen from Pearl Bank.  $R/r = 46 \text{ mm.}/8.5 \text{ mm.} = 5.4/1$ .

One arm has been broken and has partly regenerated.

DIAGNOSIS. A form of *Luidia maculata* differing from the typical form in having only six arms and the paxillae of the disk and proximal parts of the rays with a knob-like enlarged central spinelet about twice the height of the peripheral ones.

DESCRIPTION. The dorsal side is convex and only the centre of the disk is at all flattened. The madreporite is not visible. The dorsal paxillae of the outermost lateral row are the largest, being even larger than the supero-marginal series. Whereas the latter are square, the lateral paxillae are wider than long. Proximally four lateral series also form regular transverse rows with the supero-marginals, but midradially there are two rows of more numerous, smaller plates. Four to seven somewhat polygonal, thick, granule-like central spinelets and about 14 thinner peripheral spinelets cover each small paxilla of the centre of the arm but on the outermost lateral series there are about 12 central and 28 peripheral spinelets. On the disk also the paxillae are smaller than those on the sides of the rays as well as being round rather than rectangular. They have 1-3 (most commonly 1) very enlarged, round-topped central spinelets surrounded by about 6 less robust ones with the still more slender peripheral spinelets alternating in position with these. The central spinelet usually projects somewhat above the top of the other spinelets. Such paxillae only occur on the disk and at the bases of the arms and their round-topped central spinelets are never comparable to the paxillar spines of such species as *Luidia savignyi* (Audouin).

The infero-marginal plates lie almost entirely on the ventral side. Their longest spine is near the upper edge of the plate and reaches a maximum of 2.5 mm. in length. Proximally there may be a smaller spine dorsal to this one, contributing to the fringe of spines projecting laterally from the ambitus of the ray. On the ventral side are three, rarely four, equal-sized, pointed, erect spines, considerably shorter than the upper large one. A row of smaller spinelets runs down each side of the plate with



TEXT-FIG. 8. *Luidia maculata* var. *herdmani* var. n. (a) Paxilla of the outermost lateral series, (b) lateral, and (c) dorsal views of a disk paxilla.



a few scattered ones between the larger spines. As on the dorsal paxillae there are no pedicellariae on the infero-marginal plates.

The adambulacral plates have the usual curved, compressed, sabre-like furrow spine, followed by a larger spine also compressed laterally but which appears to be widened near the tip when viewed from a direction parallel to the furrow. A third slightly shorter and narrower spine stands behind this one backed by a three- or even four-valved pedicellaria on the outer edge of the plate. Adoral to the biggest spine there may be a single spinelet like those bordering the infero-marginal plates.

There are no pedicellariae in the furrow on the mouth plates.

The coloration, like that of typical *L. maculata* Müller & Troschel, is blotched. In spirit there are pairs of dark brown marks along the rays. Another specimen has a six-pointed brown star on the centre of the disk and the two small ones have a star effect on the disk caused by a V-shaped dark mark in each interbrachial angle. Many of the ventral spines and spinelets are dark-tipped.

VARIATIONS. In the Tuticorin specimen the pedicellaria outside the adambulacral spines is more often than not absent. Also the enlarged central spinelet on the paxillae at the base of the arms may be as much as three times as long as the other spinelets.

The small specimens ( $R = c. 15$  mm.) have very thorny-tipped peripheral spinelets on the dorsal paxillae.

REMARKS. This form only seems to differ from typical *L. maculata* in having 6 arms rather than 7–9, besides the conspicuous enlargement of the central granule of the disk paxillae. The latter feature was not encountered by Döderlein and does not occur in the British Museum material of *L. maculata*, although Fisher (1919: 169) says that in eight-armed Philippine specimens the central spinelet is often larger than the others which become progressively smaller towards the periphery of the paxilla. The two forms seem to overlap in their ranges as typical specimens of *L. maculata*, with seven or eight arms and uniform central paxillar granules, have been taken at Tuticorin and on the Pearl Bank, off Ceylon. Unfortunately, no details of locality were recorded at the time. *Luidia maculata* usually has pedicellariae on the marginal and dorso-lateral paxillae but Döderlein says that their presence is very variable and they may be completely absent, as here.

Koehler (1910a, pl. 15, fig. 2) shows a figure of the ventral side of a six-armed specimen of *L. maculata* from the Moluccas, but that number seems to have been rarely recorded.

The consistent combination of the two features—presence of only six arms and enlargement of the central spinelet of the disk paxillae—seems to be sufficient grounds for giving this form a special name.

From *Luidia penangensis* de Loriol, a six-armed species also from the Indian Ocean, with an enlarged spinelet in the middle of each paxilla (although not just on the disk and arm-bases), this form can be told at a glance by the absence of a conspicuous madreporite as well as by all the other characters—such as the occurrence of two-bladed pedicellariae on the mouth plates—which distinguish the *Quinaria* group (to which *L. penangensis* belongs), from the *Alternata* group.



QUINARIA GROUP

*Luidia hardwicki* (Gray)

Pl. 39, FIGS. 2 and 3

*Petalaster hardwickii* Gray, 1840: 183.

*Luidia hardwickii*, Perrier, 1875: 331 (1876: 251).

*Luidia forficifer* Sladen, 1889: 258, pl. 44, figs. 5 and 6, pl. 45, figs. 5 and 6; Döderlein, 1920: 278, text-fig. 3, pl. 20, figs. 28 and 29.

Type: R = 32 mm., r = 5.5 mm., R/r = 6/1, br. = 5.5 mm. Registered number 1938.5.12.12. Indian Ocean.

DIAGNOSIS. A species of *Luidia* belonging to the *Quinaria* group, with two or three lateral series of paxillae forming transverse rows with the supero-marginals; large pedicellariae present on the mouth plates and on the outer part of the adambulacral plates; a single enlarged marginal spine at the top of each infero-marginal plate, with smaller appressed spines on the ventral side of the plate.

DESCRIPTION. Three, distally two, rows of lateral paxillae form transverse rows with the supero-marginal series. The inner paxillae are progressively smaller towards the mid-radial line. At the base of the arm there are fifteen paxillae across the width, including the two supero-marginal series. Those in the middle of the ray are, of course, more numerous than the lateral ones, but also tend to be arranged in transverse and longitudinal rows.

These smaller paxillae, both in the centre of the disk and along the rays, have 1-5 central spinelets, resembling slightly elongated granules. On the arms the number is more commonly one and this one may be a little enlarged. On each small paxilla there are also 10-12 peripheral spinelets, 2-3 times as long as wide and only slightly, if at all, thinner than the central ones. The supero-marginal paxillae have up to 10 short central spinelets and about 20 longer peripheral ones. The outermost lateral series have about 8 central and 16 peripheral spinelets.

Pedicellariae seem to be absent from the dorsal side.

The madreporite is concealed by the paxillae.

The ventral side has suffered somewhat in drying, but there is a pair of very long pedicellariae projecting over the furrow from each mouth angle, about 1.5 mm. in length and very similar in size to the larger adambulacral spines. There is a curved, sabre-like furrow spine on each adambulacral plate backed by the usual longer, stouter spine and another spine not as large as the second; the three form a straight row at right angles to the furrow. Adoral to the two outer spines is a very big pedicellaria, about two-thirds as long as the longer spine and with the blades of the valves almost as broad at the tip as at the base (like those of *L. forficifer* as figured by Döderlein (1920: 278, text-fig. 3a)).

The ventro-lateral plates are very small, each one forming a little semicircle at the inner end of an infero-marginal plate. They are either bare or only have a few small spinelets. The infero-marginals have two or three appressed spines in a series down the middle of each plate, with smaller spinelets on each side. At the ambitus, which comes just below the small cluster of paxillar spinelets at the uppermost edge of the plate, is a single spine measuring about 1.5 mm. in length and just under 0.5 mm. in width

at the base. Some pedicellariae, about half the size of those on the adambulacral plates, occur on the infero-marginals.

REMARKS. This description agrees very closely with Sladen's of *L. forficifer* (1889: 258) with the exception of the infero-marginal plates, which, in the latter, have five squamiform spinelets in a row, whereas in the type of *L. hardwicki*, these spinelets are fewer and less regularly arranged. The smaller size and poor condition may account, at least partly, for this.

Although the type of *L. forficifer* from 'Challenger' station 187 (Booby Island, Torres Strait) has no pedicellariae on the infero-marginal plates, some are present in a larger co-type from station 188 (Arafura Sea near Torres Strait). There is then no character differing to an extent sufficient to separate the two specifically, so that *forficifer* becomes a synonym of *Luidia hardwicki* (Gray).

British Museum specimens named *L. hardwicki* by Bell, from Macclesfield Bank in the South China Sea, have pedicellariae on many of the dorsal paxillae, not just on the proximal marginal ones as in *L. quinaria*. Such pedicellariae are absent in the types of both *L. hardwicki* and *L. forficifer*, but their presence in other species of *Luidia* is very variable and their occurrence cannot be used as a specific character. These Macclesfield Bank specimens also have relatively few adambulacral plates bearing pedicellariae.

Two specimens from the Great Barrier Reef Expedition, named by Livingstone *L. forficifer*, also have some pedicellariae on the dorsal paxillae.

### *Luidia quinaria* von Martens

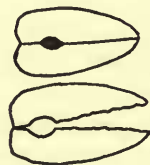
#### TEXT-FIG. 9

*Luidia maculata* var. *quinaria* von Martens, 1865: 352.

*Luidia quinaria*, Ives, 1891: 211 pl. 9, figs. 5-9; Döderlein, 1920: 244, 275, text-fig. 1.

*Luidia limbata* Sladen, 1889: 251, pl. 44, figs. 3-4, pl. 45, figs. 7-8.

One of the ten specimens of *L. quinaria* in the British Museum comes from Hakodate, in northern Japan. The pedicellariae on its mouth plates are rather thick, approximating in shape to those of *L. amurensis* Döderlein (1920: 277, text-fig. 2), from Vladivostok, which is in almost the same latitude as Hakodate.



1 mm.

TEXT-FIG. 9. *Luidia quinaria* von Martens. Pedicellariae from the mouth plates of a specimen from Hakodate, northern Japan.

Also in this specimen, as in *L. amurensis*, the pedicellariae on the marginal paxillae are little bigger than the central granules, not conspicuously larger as in specimens of *L. quinaria* from southern Japan.

The three types of *Luidia amurensis* completely lack pedicellariae on the adambulacral and ventro-lateral plates, but they are present on most of the adambulacral plates in this Hakodate specimen, although these pedicellariae are also relatively thicker than those of *L. quinaria* figured by Döderlein (p. 272, text-fig. 1b).

The two forms are obviously very closely related, and *L. amurensis* may be better placed as a northern subspecies of *L. quinaria*.

CILIARIS GROUP

*Luidia africana* Sladen

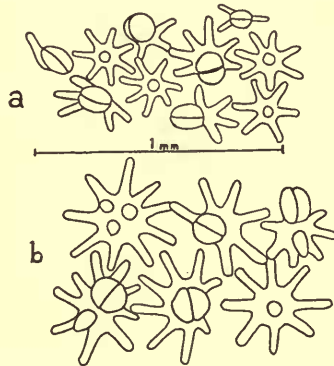
*Luidia africana* Sladen, 1889: 256, pl. 44, figs. 1 and 2, pl. 45, figs. 1 and 2; Mortensen, 1933a: 239, text-figs. 3 and 4; Madsen, 1950: 188, text-fig. 4, pl. 16, figs. 3 and 4.

The types of this species are four specimens from Simon's Bay, South Africa, and one from the coast of Morocco, near Gibraltar. The latter is broken into separate arms and the only complete specimen is a South African one with  $R = 160$  mm. This is the one figured in Sladen's plate 44, although Madsen suspected those illustrations were of the Moroccan specimen, which he thought was more likely to be *Luidia atlantidea* Madsen (1950: 192). Neither of these suppositions is correct. The light stripe along the sides of the arms in the figure of the dorsal side is probably an illusion created by the comparison with the darker mid-radial line. It is impossible to tell after so long in spirit whether such a white stripe, like that of *L. atlantidea*, ever existed in the types of *L. africana*; there is certainly no trace of one now.

Comparison of the 'Challenger' Moroccan specimen with material of *Luidia atlantidea* and with specimens of *L. sarsi* from European seas as well as the types of *L. africana* from the Cape show that, surprisingly enough, Sladen was probably right in assigning it to the same species as the South African material. The specimen has relatively long, narrow, supero-marginal paxillae, not squarish ones as in *L. atlantidea*. Also the paxillar spinelets are much more slender than in *L. atlantidea*, in which, like *L. sarsi*, they are rather short and thick. The almost spherical pedicellariae are similar in shape and position to those of the other types of *L. africana*, not flattened laterally as shown in Madsen's text-figure 5d of the dorsal paxillae of a specimen of *L. atlantidea* (which resembles the North American *Luidia elegans* Perrier in this respect).



TEXT-FIG. 10. *Luidia africana* Sladen. Dorsal view of part of an arm of the 'Challenger' Moroccan specimen.

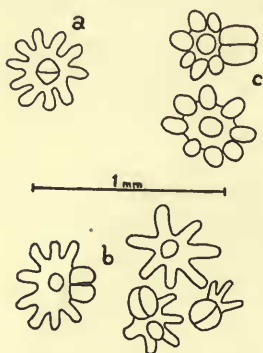


TEXT-FIG. 11. *Luidia africana* Sladen. Type specimen from Simon's Bay, South Africa. Dorsal paxillae: (a) mid-radial and (b) lateral.

As for the presence of pedicellariae, Madsen (p. 191) has emended Mortensen's statement that pedicellariae are absent on the dorsal paxillae of *Luidia sarsi* Düben and Koren by saying that they do occur, but rarely. I have found that out of ten specimens of *L. sarsi* from the north-east



Atlantic examined, four possessed dorsal pedicellariae. One of these from the Shetland Isles has only one, which is on the disk and is centrally placed on a paxilla (Fig. 12a). However, in the other three the pedicellariae are peripheral in their



TEXT-FIG. 12. *Luidia sarsi* Düben and Koren. Paxillae of specimens from (a) Shetland, (b) Rockall Bank, and (c) 'North Atlantic' ('Triton').

position on the paxillae. One from the Orkneys has a few pedicellariae on the lateral and supero-marginal paxillae, another from the Rockall Bank has many, which although still peripheral are spherical, each taking up quite a lot of the surface of the paxilla bearing it (Fig. 12b). The last of the four was taken by the 'Triton' and the only locality on the label is 'North Atlantic'. The 'Triton' collected in the Faroe channel, but this specimen may have been taken elsewhere. Its pedicellariae are numerous and again peripherally placed (Fig. 12c).

Another point made by Mortensen (1933a: 239, text-fig. 3), which needs some emendment, is that the pedicellariae of *Luidia africana* are situated in the centre of the paxillae with a complete ring of peripheral spinelets around them. I have found that out of eight specimens examined, from various localities around the Cape and including the types, the pedicellariae, when present, are almost invariably eccentrically, if

not peripherally, placed on the paxillae. I have not seen a specimen such as Mortensen's in which a perfect, uninterrupted circle of peripheral spinelets surrounds one or more central pedicellariae; in fact none of the specimens in the British Museum has such abundant pedicellariae that there are several on one paxilla. Thus it appears that the location of the pedicellariae centrally on the paxillae cannot be used as a reliable character to distinguish between *L. africana* and the other related species.

Thus in all four species—*Luidia sarsi*, *L. elegans*, *L. atlantidea*, and *L. africana*, the pedicellariae are usually peripherally, or at least eccentrically, placed on the paxillae, although they may be central in some specimens of *L. africana*. The differences between them are relatively slight. *L. atlantidea* has the supero-marginal paxillae almost square rather than nearly twice as long as wide; *L. sarsi* has the uppermost infero-marginal spine usually shorter than the second one, while it is the same length or longer in the other species; *L. elegans* has very numerous pedicellariae which are flattened laterally, and *L. africana* has the paxillar spinelets much longer and more slender than in the other three species. For all this, without knowing the exact locality of an Atlantic specimen of the *Ciliaris* group, it would not be easy to assign it to any one of the four species without abundant material for comparison.

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#### IV. *TOSIA* AND *PENTAGONASTER*<sup>1</sup>

AFTER a considerable amount of confusion aroused by the setting up of the compound genus *Astrogonium* by Müller and Troschel in 1842 and later the uncalled-for expansion of *Pentagonaster* by Perrier in 1875 and Sladen in 1889, Gray's two genera *Tosia* and *Pentagonaster* have been gradually restored to their original sense. Verrill (1899) drastically reduced *Pentagonaster* to five species and separated off two sub-genera from the species of *Tosia sensu strictu*. Fisher (1911) recognized the close relationship between the Australasian species of *Tosia* and of *Pentagonaster* as opposed to the other species that had formerly been included with them and so raised Verrill's sub-genera of *Tosia* to generic rank. Following Fisher's suggestion I have recently separated off the South African species *Tosia tuberculata* (Gray) as a new genus called *Toraster*.

Ludwig's very comprehensive paper of 1912, although unfortunately without illustrations, has brought more light on Müller and Troschel's species of *Astrogonium*, some of which prove to be identical with Gray's species. Were it not for this paper of Ludwig's, the retention of Gray's probably better-known names *aurata* and *tubercularis* might be possible, but his clarification of Müller and Troschel's previously described species makes it difficult to over-rule them on the counts of unfamiliarity and lack of definition. However, Ludwig based some of his conclusions on inadequate material, and it was not until Livingstone's work in 1932 that the extent of variation of many characters within the genus *Tosia* was realized. From the fairly large number of specimens, including Gray's types, in the British Museum, I am able to add some further remarks.

<sup>1</sup> With the production of this paper immediately after that on *Luidia*, the order of families as used by Fisher has been ignored. However, this is being rectified by reversion to the study of the family Benthoplectinidae, with which the next Note (number V) will deal.

The distinction between the genera themselves is practically confined to differences in the pedicellariae, which have long slender valves housed in corresponding grooves in the plates in *Pentagonaster* but are short and rounded, resembling a split granule when closed, if present at all, in *Tosia*. None of the other characters which have been used to distinguish them are absolutely reliable; for instance, the occurrence of swollen distal supero-marginals in *Pentagonaster* is not invariable, whereas it may occur in very marked form in certain specimens of *Tosia australis* and to a lesser extent in the West Australian species *T. nobilis* (Müller & Troschel).

H. L. Clark (1946: 88) mentions *Astrogonium inequale* Gray (1847: 79), which was put in *Pentagonaster* by Perrier and Sladen and whose generic position is in some doubt. Examination of the type, whose locality is given as 'Amboina? New Guinea?', shows that it should be placed in the genus *Sphaeriodicus* Fisher, as it originally had the dorsal, ventral, and marginal plates wholly covered with fine granules (unfortunately mostly rubbed off) and the penultimate marginals are very large, this condition being emphasized by the very small two interbrachial marginals of both upper and lower series. Contrary to Gray's statement there are  $\frac{8}{8}$  marginals only on one side of the body, three of the other sides have  $\frac{6}{8}$  and there are  $\frac{7}{8}$  on the fifth side.

KEY TO THE SPECIES OF *TOSIA* AND *PENTAGONASTER*

1. Pedicellariae with long narrow valves fitting into corresponding grooves in the plates when opened right out (Text-fig. 13); ventro-lateral plates always bare, with only a single ring of granules surrounding each plate. *Pentagonaster* 2
2. Pedicellariae large, the groove of each bivalved one over 1 mm. long, the valves finger-like with slightly swollen ends, occurring mainly on the ventral side, rarely also dorsal; terminal plates small. New Zealand. *P. pulchellus* Gray
- 2'. Pedicellariae small, tapering, the corresponding groove of each bivalved one about 0.6 mm. long, only in very large specimens nearly 1 mm. long, occurring predominantly on the dorsal side, but often also numerous ventrally; terminal plates large. Australia. 3
3. Supero-marginals not more than five on each side of each arm, distal ones more or less swollen. Western and southern Australia. *P. dubeni* Gray
- 3'. In some larger specimens more than five supero-marginal plates, the distal ones not swollen or enlarged. South and south-east Australia. *P. dubeni* forma *gunni* Perrier
- 1'. Pedicellariae if present at all, with short rounded valves, the whole hardly, if at all, larger than the neighbouring granules or spinelets (Text-fig. 14); ventro-lateral plates sometimes completely covered with granules or quite bare with only a bordering row. *Tosia* 4
4. Terminal plate swollen and conspicuous, the distalmost two supero-marginals of each arm not in contact behind it. Queensland. *T. queenslandensis* Livingstone
- 4'. Terminal plate small and inconspicuous, the last two supero-marginals usually (but not always) in contact. 5
5. Body-form almost a straight-sided pentagon with R/r about 1.3/1 and not more than three supero-marginal plates on each side of each arm. *T. australis* Gray



- 5'. Interbrachial arcs distinctly concave with R/r more than 1.4/1 or else more than three supero-marginals. 6
6. Number of marginals increasing from three to eight, being three only in specimens with R less than 12 mm., four in those with R about 15 mm., five or more when R is 20 mm. or more. Marginals gradually decreasing in size distally.  
*T. magnifica* (Müller & Troschel)
- 6'. Number of supero-marginals three or four when R is 20–35 mm., rarely five in specimens larger than that. Often one of the distal supero-marginals is larger than the rest. 7
7. Number of supero-marginals very rarely more than three. Ventro-lateral plates often covered with granules but sometimes bare. Marginal plates swollen and the arms often blunt-ended because of this. South Australia and Tasmania.  
*T. australis* forma *astrologorum* (Müller & Troschel)
- 7'. Number of supero-marginals often four when R is about 20 mm. or more, even five in larger specimens. Ventro-lateral plates always bare (judging from the known material). Supero-marginal and mid-radial dorsal plates often tubercular or just convex, the marginals relatively narrow in dorsal view. Arms tapering to an acute tip. Western Australia. *T. nobilis* (Müller & Troschel)

### PENTAGONASTER Gray

DIAGNOSIS. A genus of the Goniasteridae with more or less pentagonal body form; the dorsal and marginal plates flat or convex, not tabulate or spiny, the limits of these and also of the ventral plates, outlined by single rows of peripheral granules; the marginal plates very large, often, but not always, somewhat tubercular or swollen, especially the distal ones; pedicellariae with two or three elongated valves sunk into corresponding grooves in the plates bearing them; adambulacral armature very short and compact, so that the furrow spines and the granules behind them tend to be angular. Australasia. Type: *Pentagonaster pulchellus* Gray, 1840.

#### *Pentagonaster pulchellus* Gray

TEXT-FIG. 13a, PL. 42

*Pentagonaster pulchellus* Gray, 1840: 280; 1866: 11, pl. 8, fig. 3; Ludwig, 1912: 9; Mortensen, 1925: 281, text-fig. 7, pl. 12, fig. 6–10.

*Stephanaster elegans* Ayres, 1851: 118.

*Pentagonaster abnormalis* Gray, 1866: 11, pl. 8, figs. 1 and 2.

DIAGNOSIS. A species of *Pentagonaster* with large pedicellariae, of which the corresponding grooves in the plates measure 1.2–1.7 mm. in length and which are situated exclusively or mainly on the ventral plates, rarely on the dorsal side; three supero-marginal plates on each side of an arm or the large, occasionally swollen distalmost one is replaced by two, often more or less unequal ones; in very large specimens the supero-marginals may become separated from each other by small interstitial plates of similar size to the neighbouring dorso-lateral plates; the infero-marginals outnumber the upper series but they correspond in position to the supero-marginals



almost exactly, except for the one or two extra distal plates which are abruptly smaller than the one which lies below the distalmost supero-marginal; granules surrounding the ventral plates coarse and usually projecting from the under surface of the body; in specimens with  $R = 40$  mm. or more there are a number of secondary plates on the dorsal side near the centre of the disk.

*Table of the specimens of Pentagonaster pulchellus in the British Museum*

Reg. No.	R/r in mm.	Locality	Remarks	Size of distal supero-marginals
1938.6.23.43	59/35 = 1.71	'China'	TYPE	4
48.2.9.3	34/20 = 1.7	'India'	TYPES of	2
48.2.9.2	45/24 = 1.9	"	<i>abnormalis</i>	1
55.3.31.9	31/18 = 1.7	New Zealand		3
55.3.31.10	14/9 = 1.6	"		3
55.3.31.10	15/10 = 1.5	"		3
49.12.19.2	33/19 = 1.7	"		4
49.12.19.3	29/18 = 1.6	"		1
52.5.21.19	62/38 = 1.6	"		3
52.5.21.20	45/29 = 1.6	"		3
75.1.5.20	39/22.5 = 1.7	"		2
44.4.29.130	34/21 = 1.6	"		1
84.12.18.1	50/31 = 1.6	'Australia'		3
51.3.12.17	33/19 = 1.7	'China'		4
1949.2.4.2	60/40 = 1.5	"		3
1949.2.4.2	62/41 = 1.5	"		2
1949.2.4.2	55/35 = 1.6	"		3
1949.2.4.2	44/26.5 = 1.8	"		1
1949.2.4.2	43/29 = 1.5	"		2
1949.2.4.2	58/36 = 1.6	"		1
1949.2.3.2	35/22 = 1.6	No data		4
1949.2.3.2	31/18 = 1.7	"		2

Range of R/r = 1.5-1.9. Average = 1.6/1.

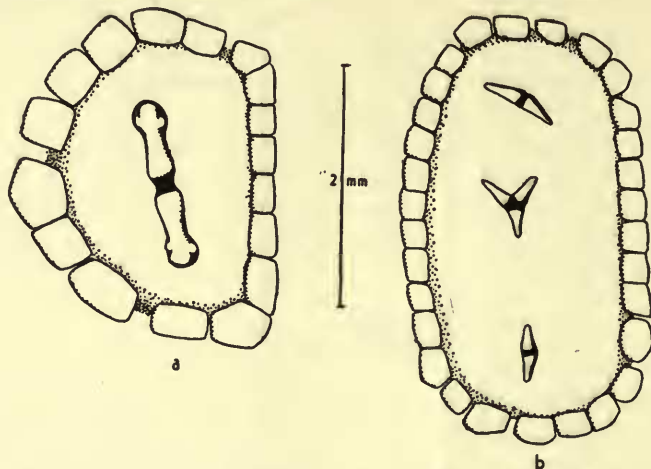
*Note:* The numbers in the last column signify grades of swollenness of the last supero-marginal on each side of each arm, 1 being not swollen (as in Pl. 42, fig. 2) and 4 very swollen (as in Gray's figure of the type).

REMARKS. Mortensen has given a detailed description and photographs of this species, of which his plate 12, fig. 9, most resembles the type, although the majority of specimens have the less extreme form with only slightly swollen distal supero-marginals, as shown in his figs. 7 and 8.

Nine of the above specimens are definitely from New Zealand; the 'Chinese' and 'Indian' ones were possibly so labelled by vendors thinking that an exotic locality would fetch a better purchasing price than none! Although one specimen is labelled as coming from Australia, no details are given and it may be a mistake; certainly it does not provide sufficient grounds for extending the known range of the species from New Zealand to Australia. A specimen from Tasmania formerly named *P. pulchellus* turned out to be a form of *Tosia australis* with very swollen distal supero-marginals (Pl. 45, fig. 1). It was easily distinguished by the lack of pedicellariae on the ventral plates and the much finer peripheral granules, as well as the absence of secondary

plates (except the anal) among the primaries in the centre of the disk. Also the five primary interradial plates are conspicuously enlarged in contrast to the usual condition in *P. pulchellus*.

The only other observation I have to make concerning this species is the fact that in three out of the six spirit specimens from 'China' mentioned above, the mid-radial row of dorsal plates as well as a few others are more or less markedly elevated into quite conspicuous tubercles about 3 mm. high, just as in the type of H. L. Clark's species *Pentagonaster stibarus* from Western Australia (1914, pl. 17). That these



TEXT-FIG. 13 (a) *Pentagonaster pulchellus* Gray, type, a ventral plate with a pedicellaria. (b) *Pentagonaster dubeni* Gray, type, a dorsal plate with three pedicellariae.

specimens are not identical with that form is shown by the fact that the pedicellariae are on the ventral side rather than the dorsal. I give here a photograph of the specimen which shows this 'tubercular' condition most clearly (Pl. 42, fig. 5).

RANGE: New Zealand—South Island and southern part of North Island; Stewart Island; ? Chatham Islands.

### *Pentagonaster dubeni* Gray

TEXT-FIG. 13b; PLS. 43 and 44

- Pentagonaster dubeni* Gray, 1847: 79; 1866: 11, pl. 3, fig. 2; Ludwig, 1912: 18; H. L. Clark, 1928: 380; Livingstone, 1932, pl. 44, figs. 4 and 5; H. L. Clark, 1938: 79; 1946: 88.  
*Astrogonium crassimanum* Mobius, 1859: 8, pl. 2, figs. 1 and 2.  
*Pentagonaster crassimanus*, H. L. Clark, 1946: 89.  
*Pentagonaster gunni* Perrier, 1875: 203 (1876: 19).  
*Pentagonaster stibarus* H. L. Clark, 1914: 136, pl. 17.

DIAGNOSIS. A species of *Pentagonaster* with small pedicellariae, the corresponding grooves in the plates 0.4–0.9 mm. in length, usually about 0.6 mm., lying on both

dorsal and ventral sides as a rule, rarely few in number and absent ventrally; supero-marginal plates four to eight on each side of an arm, the distal ones more or less swollen, especially when there are only four or five; the infero-marginal plates invariably outnumber the upper series by about two plates and decrease gradually in size distally; the granules surrounding the ventral plates fine and unobtrusive; adambulacral armature compact; few, if any, secondary plates interposed among the primary ones in the centre of the disk, even when R is as much as 40 mm.

*Table of the specimens of Pentagonaster dubeni Gray in the British Museum (Nat. Hist.)*

Reg. No.	R/r in mm.	Number and condition of supero-marginal plates	Locality	Number	Remarks
46.6.7.27	37/18 = 2.1/1	5. The last two a little enlarged and swollen	W. Australia	1	TYPE
60.11.7.5	48/20 = 2.4	5. Penultimate largest but not swollen	Freemantle, W.A.	1	—
52.12.9.20	37/16 = 2.3	4. Last 1 or 2 enlarged and very swollen	Moreton Bay, Queensland	1	? <i>dubeni</i>
49.11.19.163	47/18 = 2.6	8. Last smaller but rest all same size	Georgetown, Tasmania	1	TYPE of <i>P. gunni</i>
1951.2.28.1-11	41/17 = 2.4 to 22/10 = 2.2	4 (rarely 3 or 5). Last 1 (or 2) swollen	Point Peron & Garden Island, W.A.	19	—

REMARKS. H. L. Clark queries the locality of the type on the basis that as 'China' was wrong for the type of *Pentagonaster pulchellus*, so might 'Western Australia' be wrong for that of *P. dubeni*. This may be so, but the locality is supported by the Freemantle specimen collected by Dr. Bowerbank, which has convex dorsal plates and five supero-marginals like the type, although all the recent Point Peron and Garden Island specimens have more than four only on individual sides. I am indebted to Miss L. Rutt of the Biology Department, University of Western Australia, who collected and sent these specimens at my request. They are very similar in appearance to the type of *P. stibarus* H. L. Clark, from between Freemantle and Geraldton in 40-100 fathoms, except for slightly deeper interbrachial arcs and the absence of the tubercular mid-radial plates found in the latter. H. L. Clark has since reduced his species to a synonym of *P. crassimanus* (Möbius), the type of which was of problematical locality. Ludwig gives the R/r ratio of the type of *P. crassimanus* as 1.84/1; that of *P. stibarus* is 2/1, while the value for the Western Australian specimens in the British Museum varies between 2 and 2.4/1.

Some of the Point Peron and Garden Island specimens have slightly convex mid-radial plates, but in the type and the Freemantle specimen nearly all the dorsal plates are markedly convex. Apart from this character, which is very variable in *Pentagonaster* and related genera, there is no feature of sufficient significance to distinguish between the *stibarus*-like form and the type of *P. dubeni*. Ludwig's fuller description of the type of *P. crassimanus* brings out no detail, except perhaps for the shorter arms, in which it differs significantly from the type of *P. dubeni*, although Ludwig sets out five distinguishing points as follows: *P. crassimanus* has (1) wider arm-tips, (2) fewer supero-marginals relative to the absolute size, (3) the distal



supero-marginals more swollen, (4) the bordering granules around the plates coarser, and (5) the adambulacral spines more compact than in *P. dubeni*. Of these, factors 1 to 3 are very variable and utterly useless as specific characters in this genus, 5 is unlikely as the adambulacral armature of the type of *P. dubeni* is already very compact and 4 is probably not significant either, at least without direct comparison of specimens.

There are three furrow spines on each adambulacral plate in the type of *P. dubeni* and in all the larger (i.e. over 40 mm. R) specimens in the British Museum. The fact that those of adjacent plates tend to overlap may have given rise to the discrepancy in the numbers given by some authors. Smaller specimens have only two furrow spines at least distally.

H. L. Clark (1946), believes there is a specific difference between the Western Australian form, which he calls *P. crassimanus*, and the southern Australian form, which he calls *P. dubeni*, evinced mainly by the larger number of dorsal and ventral plates in juvenile specimens of the southern form than in others the same size from Western Australia. This difference does not seem to be shown in the adult, at least judging from the comparison of the type of *P. dubeni* with that of *P. gunni* from Tasmania, which is unfortunately the only specimen from the south in the British Museum collection. The type of *P. gunni* also shows the other feature which H. L. Clark noticed in his material from the South Australian Museum, namely that there may be more than five supero-marginals on each side of an arm in larger specimens and these become smaller distally. When there are only about five plates though, the distal ones may be swollen and larger than the interradials. H. L. Clark's specimen with most supero-marginal plates had seven on each side and R was 54 mm., whereas the type of *P. gunni* has eight with R = only 47 mm. and so is even more extreme.

Miss Rutt has provided some colour notes for the specimens from Point Peron and Garden Island, south of Freemantle. These were collected just below low-water level among seaweed on rock platforms. The colour was very variable, ranging through pale flesh-pink, deeper salmon-pink, pale brick-red, light orange, brilliant crimson, and bright orange, the last being the commonest. The granules between the plates were white. H. L. Clark gives bright vermilion, with white between the plates for a specimen from Port Jackson, New South Wales.

Since *Pentagonaster dubeni* is preoccupied for the Western Australian form, the southern form, if specifically distinct, will have to be called *P. gunni*, but with the present sparse material and the conspicuous gap geographically in our knowledge of the species along the south Australian coast westwards towards Albany and Bunbury, it seems best to leave them as a single species *P. dubeni* for the present.

Possibly *crassimanus* can also be retained as a name for the short-armed form of *dubeni* from deeper water (40-100 fathoms) off Western Australia.

As for the Queensland specimen, this is superficially very similar to the type of *P. dubeni* but it has very sparse pedicellariae (five or six on the dorsal side only), which are even smaller than in the other specimens, measuring only 0.4 mm. in length. Also the supero-marginal (particularly the distal) plates and the dorsal plates have a roughened surface like those of Livingstone's species *Tosia queenslandensis*, known

only from juvenile specimens without pedicellariae. Here again more material is wanted which I think will indicate that that species would be better placed in the genus *Pentagonaster* and that this specimen represents the adult form of it.

RANGE. Western, southern, and south-eastern Australia; ? Queensland.

**TOSIA** Gray

DIAGNOSIS. A genus of the Goniasteridae with the body more or less pentagonal in form having a limited number (three to eight) of supero-marginal plates on each side of each arm; the dorsal and marginal plates flat or convex and bare but for one (rarely two) rows of bordering granules; ventro-lateral plates similarly bare or more or less completely covered with additional granules; the five primary plates of the dorsal side usually conspicuously larger than the other dorsal plates; adambulacral plates with two (three in large specimens) short spines in each of the two rows nearest the furrow, backed by several rows of granules; pedicellariae, if present at all, with two short, wide valves, the whole not or hardly larger than one of the surrounding granules, situated on either dorsal or ventral side, particularly on the adambulacral plates. Australia and Tasmania. Type: *Tosia australis* Gray 1840.

REMARKS. The synonymy of the species within this genus is in a very muddled state owing to the ignoring of Müller and Troschel's species by Gray and the failure of these authors to realize the extent of variation in the granulation of the ventral plates and in the concavity of the interbrachial arcs as well as the increase in the number of marginal plates with size in some of the species (particularly *T. magnifica*). Livingstone (1932: 373) has detailed the variation of these characters in the different species. Unfortunately he did not have access to Ludwig's paper of 1912, which sheds much light on Müller and Troschel's type specimens, consequently necessitating some departure from Gray's specific names which I have further emended here.

Original name	Ludwig's emendment	Present view
<i>australis</i> Gray, 1840	Valid	Valid
<i>magnifica</i> (Müller & Troschel), 1842	Valid	Valid
<i>astrologorum</i> (Müller & Troschel), 1842	= <i>australis</i>	forma of <i>australis</i>
<i>geometricum</i> (Müller & Troschel), 1842	= <i>australis</i>	= <i>australis</i>
<i>australe</i> , (Müller & Troschel), 1842	—	= <i>magnifica</i>
<i>ornata</i> (Müller & Troschel), 1842	= <i>australis</i>	= <i>magnifica</i>
<i>nobilis</i> (Müller & Troschel), 1843	Valid	Valid
<i>grandis</i> Gray, 1847	= <i>magnifica</i>	= <i>magnifica</i>
<i>aurata</i> Gray, 1847	Valid	= <i>magnifica</i>
<i>tubercularis</i> Gray, 1847	= <i>nobilis</i>	= <i>nobilis</i>
<i>rubra</i> Gray, 1847	= <i>australis</i>	= <i>nobilis</i>
<i>emilii</i> (Perrier), 1869	= <i>aurata</i>	= <i>magnifica</i>
<i>minimus</i> (Perrier), 1875	—	juvenile <i>australis</i> or <i>nobilis</i>
<i>queenlandensis</i> Livingstone, 1932	—	Valid. <i>Pentagonaster</i> ?

Most adult specimens of the genus *Tosia* can be quite easily identified, but juvenile specimens, particularly of *T. nobilis* and *T. australis*, can be confused.

*Tosia australis* Gray<sup>1</sup>

TEXT-FIG. 14, PL. 45, FIGS. 1 and 2, PL. 46, FIG. 3.

- Tosia australis* Gray, 1840: 281; 1866: 11, pl. 16, fig. 1; Verrill, 1899: 160; Ludwig, 1912: 23; H. L. Clark, 1928: 381; Livingstone, 1932: 375, pl. 43, figs. 10-13, pl. 44, fig. 6; H. L. Clark, 1946: 94. [non *Astrogonium australe*, Müller and Troschel, 1842: 55.]
- Pentagonaster australis*, Perrier, 1875, 200 (1876: 16).
- Astrogonium astrologorum* Müller and Troschel, 1842: 54.
- Pentagonaster astrologorum*, Perrier, 1875: 196 (1876: 12).
- Tosia australis* var. *astrologorum*, H. L. Clark, 1928: 384; Livingstone, 1932: 376.
- Astrogonium geometricum* Müller and Troschel, 1842: 54.
- Tosia tubercularis*, Livingstone, 1932: 378, pl. 44, figs. 1, 2, and 7. [non *Tosia tubercularis* Gray, 1847: 80.]

DIAGNOSIS. A species of *Tosia* with three (rarely four) supero-marginal plates on each side of each arm, of which the distalmost may or may not be enlarged; the dorsal plates usually flat, but in some specimens, particularly from Tasmania, the dorsal and supero-marginal plates may be markedly convex; pedicellariae sometimes present but only in small numbers, on either dorsal or ventral side, often only on a few of the adambulacral plates; body form typically almost a straight-sided pentagon with  $R/r = c. 1.35/1$ , but in the forma *astrologorum* the interbrachial arcs can be much more concave so that the  $R/r$  ratio may exceed  $1.5/1$ .

REMARKS. There are fifty-two specimens of *Tosia australis* in the British Museum, of which twenty-six are detailed in the table on p. 405. The first specimen listed, 43.3.10.26 (Pl. 45, fig. 2; Pl. 46, fig. 3), is the one figured by Gray and is therefore presumably the type although not labelled as such.

Unlike *Tosia magnifica* the number of supero-marginal plates does not normally increase with size, so that with the single exception of one of the 'Challenger' specimens from Sydney Harbour (Port Jackson), all of these have only three supero-marginal plates on each side of each arm. The exception has four on most sides. The locality or identity of these 'Challenger' specimens has been queried by Livingstone on the grounds that no further material of this species has since been found in Port Jackson. Sladen named the specimens *Pentagonaster astrologorum* (Müller and Troschel). They are not young *P. dubeni* as Livingstone suggested might be the case, as for one thing the terminal plates are very small. The collector's label within the jar clearly says 'Sydney Harbour'. The dimensions are as follows:  $R/r$  in mm. =  $19/12.5 = 1.5/1$ ;  $18/13 = 1.4/1$ ;  $16/10.5 = 1.5/1$ ;  $15/10 = 1.5/1$ ;  $14/9 = 1.6/1$ ; and  $10.5/7.5 = 1.4/1$ . It is only the largest one which has four supero-marginals. The ventral plates in every case are completely covered with granules, and each specimen has at least one rounded pedicellaria on the ventral side, usually near the mouth. The marginal plates are slightly swollen.

<sup>1</sup> The *Asterias procyon* of Valenciennes (manuscript), published by Cuvier in the *Règne Animal* (Disciples edition) vol. 20: Zoophytes, pl. 1, fig. 2, is either this species or *Tosia nobilis*, more probably the latter since it is said to have been collected by Quoy and Gaimard in King George's Sound, south-western Australia, although in appearance it is rather more like *T. australis*. The date of this publication is presumed to be 1838 (see Sherborn, 1922, *Ann. Mag. Nat. Hist.* (9) 10: 555). It is surprising that neither Müller and Troschel nor Perrier, all of whom probably had access to Valenciennes manuscript, do not quote this species. Since it is not positively identifiable it should be declared a *nomen nudum*.



Table of the specimens of *Tosia australis* Gray in the British Museum (Nat. Hist.)

(Those below the dividing line belong to the forma *astrologorum*)

Reg. No.	R/r in mm.	Number of infero-marginals	Locality
43.3.10.26	23.5/18 = 1.3/1	5	—
40.10.17.87	19.5/14 = 1.4	5	—
53.11.22.33	22/18 = 1.2	4	Australia
53.11.22.31	22/17 = 1.3	5	"
85.11.19.43	15/12 = 1.25	4	Port Phillip Heads
63.9.23.43a	16/13 = 1.2	4	Australia
90.5.7.393	19/12.5 = 1.5	5	Sydney Harbour
90.5.7.394	18/13 = 1.4	4	"
62.7.9.55	20/15 = 1.3	5	Dirk Hartog Island, W.A.
62.7.9.69	14/10.5 = 1.3	4	"
57.3.20.15	17/13 = 1.3	4	Port Dalrymple, Tasmania
54.11.15.304	20/14 = 1.4	5	"
54.11.15.304a	17/12 = 1.4	4	"
40.3.9.2	17/12 = 1.4	4	Tasmania
62.1.8.20	27/19 = 1.4	6	"
62.1.8.21	25/20 = 1.3	5	"
49.11.19.159	20/14 = 1.4	5	Georgetown, Tasmania
49.11.19.146	17/13 = 1.3	4 (5)	"
49.11.19.158	20/15 = 1.3	4	"
49.11.19.155	20/13 = 1.5	5	Georgetown, Tasmania
49.11.19.156	19/13 = 1.5	5	"
49.11.19.153	30/20 = 1.5	6	"
1916.8.10.1	23/17 = 1.4	4 (5)	Tasmania
62.1.8.19	30/19 = 1.6	6	"
40.10.17.88	22/15 = 1.5	6	—
43.3.10.26a	32/21 = 1.5	5	—

The occurrence of pedicellariae in the species *Tosia australis* seems to be a matter of some doubt. Livingstone says that pedicellariae are absent in typical *T. australis* and in the variety *astrologorum*, at least on the ventral side of the latter. Ludwig found pedicellariae on the dorsal side of five out of fourteen specimens. I also have found them on the dorsal side of at least five specimens of *T. australis* and on the ventral side of ten (three specimens having them on both sides), besides the six 'Challenger' specimens.

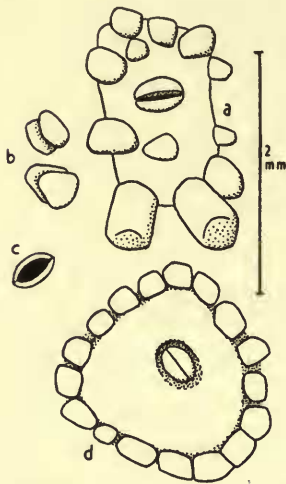
Livingstone figures a specimen from Victoria (pl. 44, figs. 1, 2, and 7), which he calls *T. tubercularis* Gray (i.e. *nobilis*). It does not belong to that species, which is confined to Western Australia, but should instead be named *T. australis* forma *astrologorum* although it has four supero-marginals. There are several specimens in the British Museum intermediate in form between this Victorian one and the more usual type as shown in Livingstone's pl. 43, figs. 1 and 2, which he acknowledges as *astrologorum*.

Ludwig also had some specimens which he considered to be *Tosia australis* with four supero-marginals, although most of his had the usual three.

Müller and Troschel's as well as Perrier's descriptions of the types of *astrologorum* leave room for some doubt that their specimens were not the Western Australian species to which the first-named authors gave the name *Astrogonium nobile* in 1843

(p. 116). The description and locality of the type of the latter show that it is undoubtedly identical with Gray's *Tosia tubercularis* described in 1847. Perrier (1875: 197) gives the measurements of the largest Parisian type of *astrologorum* as

$R/r = 35/21 = 1.67/1$ . Müller and Troschel write that the last of the three supero-marginal plates is very large and corresponds to three infero-marginals which could apply either to *T. nobilis* or to the longer-armed form of *T. australis*. However, the fact that there may be up to seven infero-marginals corresponding to the three supero-marginals according to Perrier is rather more conclusive in pointing to the identity of *astrologorum* with *T. nobilis*, for only in the latter have I found more than six infero-marginal plates, the number being habitually seven for specimens with R more than 30 mm. Perrier also says that there may be a very small distal fourth supero-marginal, which again indicates the Western Australian species.



TEXT-FIG. 14. *Tosia australis* Gray, specimen 49.11.19.158. (a) Proximal adambulacral plate with non-sunken pedicellariae. (b) Other adambulacral pedicellariae. (c) Foramen of pedicellaria of which the valves have been rubbed off. (d) Ventral plate with pedicellaria sunk in a hollow.

However, these points are not sufficiently conclusive to abandon, without examination of the types, the now fairly stabilized conception of *astrologorum* as a longer-armed form of *Tosia australis* with more or less swollen marginal plates.

The record of typical *Tosia australis* from Dirk Hartog Island, Sharks Bay, about 450 miles north of Freemantle, needs confirmation from more recent collections.

RANGE. Both the typical form and *astrologorum* appear from various reports to occur in South Australia, Victoria, and Tasmania and possibly also from Port Jackson. The British Museum material suggests that

the latter is most common in Tasmania.

### *Tosia nobilis* (Müller and Troschel)

PL. 45, FIGS. 3, 4, 6, and 7; PL. 46, FIGS. 1 and 2

*Astrogonium nobile* Müller and Troschel, 1843: 116.

*Tosia tubercularis* Gray, 1847: 80; 1866: 11, pl. 16, fig. 4. [non *Tosia tubercularis* Livingstone, 1932: 378, pl. 44, figs. 1, 2, and 7.]

? *Tosia rubra* Gray, 1847: 81; 1866: 11, pl. 16, fig. 3; Livingstone, 1932: 380.

*Tosia nobilis*, Ludwig, 1912: 30.

DIAGNOSIS. A species of *Tosia* with evenly tapering arms; three to five supero-marginal plates on each side of each arm, the distalmost, or more rarely the penultimate, elongated when there are three or four, or subdivided in very large specimens to make five with the distalmost the smallest; dorsal plates, particularly the radial ones, conspicuously convex, as are the supero-marginals, although the latter are not

much swollen laterally and are usually relatively narrower than those of *Tosia australis*; the convexity of the supero-marginals may assume a conical form with a distinct peak on each plate; interbrachial arcs rather deep with R/r usually more than 1.5/1; ventro-lateral plates usually (? always) bare. Western Australia.

Table of the specimens of *Tosia nobilis* (Müller and Troschel) in the British Museum (Nat. Hist.)

(The first two are the types of *T. tubercularis* Gray and the last one the type of *T. rubra* Gray)

Reg. No.	R/r in mm.	Number of supero-marginals	Number of infero-marginals	Locality
46.8.14.3	30/18 = 1.7/1	4	6	Swan River, W.A.
46.8.14.4	25/16 = 1.6	3	6	"
46.8.14.5	16/12 = 1.3	3	5	"
63.9.23.43	11/7 = 1.6	4	5	'Australia'
60.11.7.8	20/14 = 1.4	3	6	Freemantle, W.A.
60.11.7.9	21/14 = 1.5	3	6	"
61.7.8.25	23/14 = 1.6	4	6	"
61.7.8.26	19/12.5 = 1.5	3	5	"
61.7.8.27	18/12 = 1.5	3 (4)	5	"
46.6.7.28	24/16 = 1.5	4	6	Western Australia
72.6.22.21	29/17 = 1.7	5 (4)	7	—
40.10.4.2	18/11 = 1.6	4	6	'New Holland'
1949.2.3.6	32/21 = 1.5	4	7	—
1951.4.3.1	22/14 = 1.6	3 (4)	6	—
1951.4.3.1a	20/12.5 = 1.6	4	6	—
1951.2.28.12-17	39/24 = 1.6	5	7 (8)	Garden Island, south of Freemantle, W.A.
"	37/23.5 = 1.6	3	7	"
"	36/20.5 = 1.8	4	7	"
"	35/21 = 1.7	3	7	"
"	30/18 = 1.7	3 (4)	7	"
"	27/18 = 1.5	3	7	"
"	25/15 = 1.7	4	5 (6)	"
"	25/17 = 1.5	3 or 4	6	"
"	20/13 = 1.5	4	6	"
"	20/13 = 1.5	3	5	"
1938.5.12.10	33/20 = 1.7	5	7	'Australia'

Average R/r = 1.6/1.

REMARKS. The material in the British Museum suggests that *Tosia nobilis* grows to a larger size (R = up to 40 mm.) than *Tosia australis*, of which the typical form rarely exceeds R = 24 mm. and the forma *astrologorum* about R = 33 mm. However, more material may serve to disprove this statement.

Further material from Garden Island, sent by Miss Rutt, includes three specimens with R = c. 35 mm., one with three supero-marginals, another with four, and the third with five, which shows the variability of this character in *Tosia nobilis*. There is also a specimen with six regular arms.

Livingstone's specimens, which he called *Tosia tubercularis*, originated from Victoria and in spite of the relatively deep interbrachial arcs are quite distinct from the Western Australian form, judging from his photographs. They should instead be assigned to the forma *astrologorum* of *Tosia australis*. The differences between the



two are rather intangible and can be better expressed by photographs than words. The arms are invariably evenly tapering with only a slight rounding of the tip in *T. nobilis*, although they may be so in some specimens of *astrologorum* too; also the supero-marginals tend to be relatively narrower in *T. nobilis* than in most examples of *astrologorum*. With a large number of specimens of both forms, it is fairly easy to pick out the Western Australian ones, but without such material for comparison some difficulty may be encountered. Whereas *T. nobilis* is geographically distinct from typical *T. australis* unlike *astrologorum*, it might be better to consider it as a subspecies of *Tosia australis*, if the differences are not thought to be specific.

The ventro-lateral plates (at least proximally) are in every case bare but for the single peripheral ring of granules around each. It was this which finally prompted me to include *Tosia rubra* Gray as a synonym of *T. nobilis* rather than of *T. magnifica*; for although the type of the latter, from Tasmania, had the ventral plates quite bare, in all but one of the specimens in this Museum only the proximal plates, if any, are bare, or else there is a double row of granules around each plate. The type of *T. rubra* has the ventral plates bare like *nobilis*. Of the five supero-marginal plates none is enlarged and the distalmost is the smallest, as in *T. magnifica* but also as in those specimens of *T. nobilis* which do have five marginals. It is linked with *Tosia nobilis* by another specimen, number 1949.2.3.6 (Pl. 45, fig. 7), which has four supero-marginals, the penultimate being enlarged. Unfortunately neither of these two has any locality other than 'Australia'. It is to be hoped that more of these intermediate forms between *Tosia nobilis* and *T. magnifica* on the one hand, or *T. australis* forma *astrologorum* on the other, will be forthcoming in future collections to clarify the position.

Livingstone reports some specimens, which he includes under *Tosia australis*, from King George's Sound and Esperance at the western end of the south coast of Australia. Material from this area should be very interesting, possibly connecting up *Tosia australis* with *T. nobilis*, but unfortunately the Australian Museum specimens from these localities are all juvenile.

RANGE. Known at present only from Western Australia in the vicinity of Fremantle.

### *Tosia magnifica* (Müller and Troschel)

PL. 45, FIG. 5; PL. 46, FIGS. 4 and 5

*Astrogonium magnificum* Müller and Troschel, 1842: 53, pl. 4, fig. 1.

*Astrogonium australe*, Müller and Troschel, 1842: 55.

*Astrogonium ornatum* Müller and Troschel, 1842: 55.

*Tosia grandis* Gray, 1847: 80; 1866: 11, pl. 3, fig. 1; Livingstone, 1932: 380.

*Tosia aurata* Gray, 1847: 80; 1866: 11, pl. 16, fig. 2; Ludwig, 1912: 34; Livingstone, 1932: 377, pl. 43, figs. 3-9, pl. 44, fig. 3.

*Astrogonium emilii* Perrier, 1869: 84.

*Pentagonaster auratus*, Perrier, 1875: 204 (1876: 20).

*Tosia magnifica*, Ludwig, 1912: 36.

DIAGNOSIS. A species of *Tosia* with evenly tapered arms, the distalmost supero-marginals showing no tendency for enlargement or swelling, being usually smaller than the penultimates; the number of marginals tends to increase with size up to eight on

each side of each arm in specimens where R = about 70 mm. and even young specimens with R = only 10 mm. have often four, rather than three, supero-marginals; ventro-lateral plates usually covered with granules, but sometimes more or less bare especially the proximal ones.

*Table of the specimens of Tosia magnifica (Müller and Troschel) in the British Museum (Nat. Hist.)*

Reg. No.	R/r in mm.	Number of supero-marginals	Locality and remarks
43.II.2.134	27/18 = 1.5/1	6	— TYPE of <i>Tosia aurata</i>
43.II.2.134a	20/14 = 1.4	5	— TYPE of <i>Tosia aurata</i>
1938.5.12.9	77/51 = 1.5	8	Western Australia? TYPE of <i>Tosia grandis</i>
1938.5.12.21	60/37 = 1.6	7	Georgetown, Tasmania
62.1.8.17	52/35 = 1.5	6 or 7	Tasmania
87.12.7.1	52/38 = 1.4	6	"
87.12.7.1a	31/22.5 = 1.4	5	"
85.II.19.41	62/37 = 1.7	7	Port Phillip Heads
54.II.15.305	15/10 = 1.5	5	Hobson Bay, Port Phillip
54.II.15.306	6.5/5.5 = 1.2	3	"
1916.8.10.4	20/14 = 1.4	6	South Australia
1949.2.3.4	13.5/10 = 1.4	4	Adelaide, S. Australia
1949.2.3.4a	13.5/9.5 = 1.4	4	"
1949.2.3.4b	12/8.5 = 1.4	4	"
1949.2.3.4c	14/11 = 1.3	3 or 4	"
1949.2.3.4d	11/9 = 1.2	4	"
1949.2.3.4e	10/7.5 = 1.3	3 or 4	"
1949.2.3.4f	10.5/7.5 = 1.4	4 (3)	"
43.3.10.27	29/20 = 1.5	5	—
1949.2.3.5	31/21 = 1.5	6	—
49.II.19.143	37/24 = 1.5	7	Georgetown, Tasmania
49.II.19.140	50/30 = 1.7	5 (6)	"
49.II.19.140a	30/21 = 1.4	6	"
49.II.19.140b	37/25 = 1.5	7	"
49.II.19.142	42/29 = 1.5	6	"

Average R/r for specimens with R more than 15 mm. = 1.5/1.

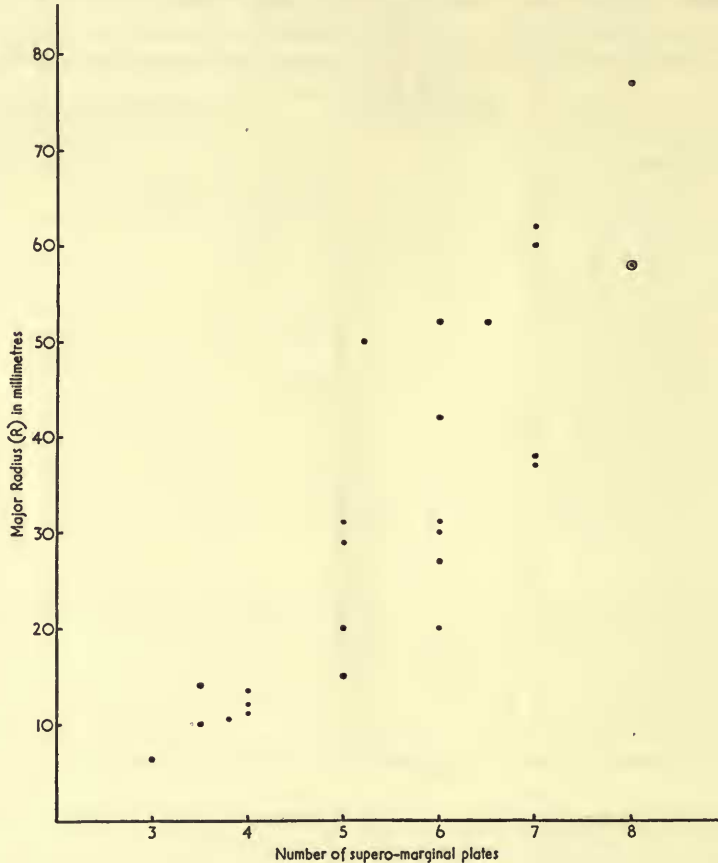
REMARKS. The multiplicity of names given to this species resulted from the independent setting up by Gray of new species for the forms already described by Müller and Troschel, besides the ignorance of both parties concerning the extent of variation in the ventral granulation and the increase in the number of marginal plates with size.

The big range of specimens in the British Museum shows that, as Livingstone suspected, the large form (described as *magnifica* and *grandis*) is clearly conspecific with the small one (*ornata-aurata*). *Magnifica* has page priority over Müller and Troschel's other name.

Livingstone queries the inclusion by Perrier of Müller and Troschel's *Astrogonium australe* as a synonym of this species on the grounds that they give the number of supero-marginals as six. However, those authors give the number for *A. geometricum (australis)* as three, so obviously they were counting the numbers on each side of each arm not on each side of the body, as Livingstone does.

In most of the specimens that I have seen, the majority, if not all, of the ventral

plates are completely covered with granules. Sometimes a single plate in some inter-radii near the mouth is bare, more often there are eight or nine bare plates in each interradius, each one usually surrounded by a double row of granules. In general the incidence of ventral granules is much higher in this species than in *Tosia nobilis* or *T. australis*, particularly the former.



TEXT-FIG. 15. Graph to show the increase in the number of supero-marginal plates with absolute size in *Tosia magnifica*, based on specimens in the British Museum except for the point ringed, which represents Müller and Troschel's type.

It is partly this predominance of ventral granules which leads me to include *Tosia rubra* Gray as a synonym of *T. nobilis* rather than of *T. magnifica*, although the abundance of granules is by no means diagnostic, the type of *T. magnifica* having nearly all the ventral plates bare.

Although the number of marginal plates increases in general with size, there is considerable variation in different individuals, as can be seen from the table. However, very young ones with the major radius R as small as 10 mm. usually have some,



if not all, the arms with four supéro-marginals on each side in contradistinction to juveniles of the other species of *Tosia*, which do not have more than three.

RANGE. Victoria, Tasmania, and South Australia.

*Tosia queenslandensis* Livingstone

*Tosia queenslandensis* Livingstone, 1932a: 243, pl. 5, figs. 1, 2, and 7; 1932: 381, pl. 44, fig. 3.

There is a paratype in the British Museum, but like the type it is juvenile. Neither of these have pedicellariae according to Livingstone, but if, as I think possible, they represent the same species as the specimen from Moreton Bay, Queensland, discussed under *Pentagonaster dubeni* in this paper, then *queenslandensis* would have to be relegated to the genus *Pentagonaster* because of the shape of the pedicellariae. Moreton Bay is about 250 miles south of the Capricorn group, the type locality of *Tosia queenslandensis*.

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(Where not otherwise stated the reproductions are natural size.)

PLATE 39

FIG. 1. *Luidia columbia* (Gray), type, dorsal view.

FIG. 2. *Luidia hardwicki* (Gray), type, dorsal view.

FIG. 3. The same in ventral view.

PLATE 40

FIG. 1. *Luidia scotti* Bell, type, dorsal view.

FIG. 2. *Luidia savignyi* (Audouin), 1904.3.3.66, dorsal view.

PLATE 41

FIG. 1. *Luidia alternata numidica* Koehler, 1910.8.3.1, dorsal view.

FIG. 2. *Luidia maculata* forma *herdmani* forma n., type, dorsal view.

FIG. 3. The same in ventral view.

PLATE 42

*Pentagonaster pulchellus* Gray

FIGS. 1 and 2. Ventral and dorsal views of the smaller type of *P. abnormalis* Gray. The least extreme form of *P. pulchellus*.

FIGS. 3 and 4. Ventral and dorsal views of the larger type of *P. abnormalis* Gray.

FIG. 5. Specimen 1949.2.4.2, dorsal view showing the tubercular mid-radial plates.  $\times \frac{1}{2}$ .

PLATE 43

*Pentagonaster dubeni* Gray

FIG. 1. Specimen 52.12.9.20, from Queensland, dorsal view.

FIG. 2. The type of *P. gunni* Perrier, from Tasmania, dorsal view.

FIG. 3. The type of *P. dubeni* Gray, from Western Australia, dorsal view.

PLATE 44

*Pentagonaster dubeni* Gray

FIG. 1. Specimen 52.12.9.20, ventral view.

FIG. 2. The type of *P. gunni* Perrier, ventral view.

FIG. 3. The type of *P. dubeni* Gray, ventral view.

PLATE 45

FIG. 1. *Tosia australis* forma *astrologorum* (Müller and Troschel), extreme form, specimen 62.1.8.19, dorsal view.

FIG. 2. *Tosia australis* Gray, specimen figured by Gray in 1866 so presumably the type, dorsal view.

FIG. 3. *Tosia nobilis* (Müller and Troschel), specimen 72.6.22.21, dorsal view.

FIG. 4. *Tosia nobilis* (Müller and Troschel), the type of *T. tubercularis* Gray, dorsal view.

FIG. 5. *Tosia magnifica* (Müller and Troschel), the type of *T. aurata* Gray, dorsal view.

FIG. 6. *Tosia nobilis* (Müller and Troschel) ?, the type of *T. rubra* Gray, dorsal view.

FIG. 7. *Tosia nobilis* (Müller and Troschel), specimen 1949.2.3.6, dorsal view.

PLATE 46

FIG. 1. *Tosia nobilis* (Müller and Troschel) ?, the type of *T. rubra* Gray, ventral view.

FIG. 2. *Tosia nobilis* (Müller and Troschel), the type of *T. tubercularis* Gray, ventral view.

FIG. 3. *Tosia australis* Gray, specimen figured in 1866, ventral view.

FIG. 4. *Tosia magnifica* (Müller and Troschel), the type of *T. aurata* Gray, ventral view.

FIG. 5. *Tosia magnifica* (Müller and Troschel), the type of *T. grandis* Gray, ventral view.